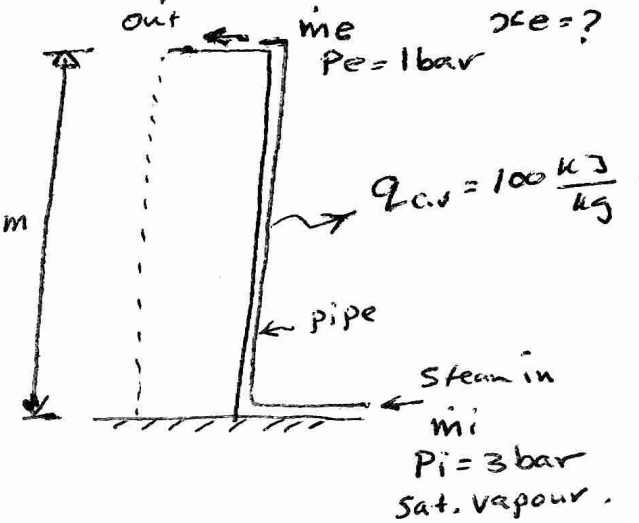
(C) : مجموعة open system لـ

ME210 ①

Examples. SSSF Process.

① Construction of a 1500m tall skyscraper specifies that steam heating be supplied. Asume that the steam is supplied to the top of the building by a vertical pipe. if the steam enters at the ground level as dry saturated vapour at 3 bar and transfers 100 $\frac{kJ}{kg}$ in its passage to the top floor where its pressure is 1 bar, Find the quality of the steam at this point.



Sol.

For SSSF
First Law

$$q_{c.v} = (h_e - h_i) + g(z_e - z_i)$$

$$h_i = h_g @ 3bar = 2725.3 \frac{kJ}{kg}$$

$$-100 = h_e - 2725.3 + \frac{9.81(1500)}{1000}$$

$$-100 - \frac{9.81(1500)}{1000} + 2725.3 = h_e = 2610.585 \frac{kJ}{kg}$$

water @ 1 bar $h_g = 2675.5 \frac{kJ}{kg} > h_e$ ∴ the water is Saturated.

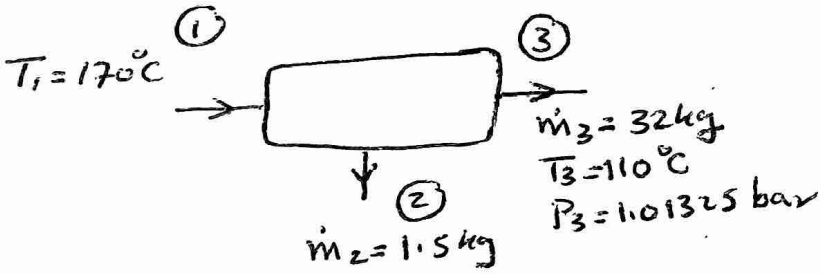
$$h_e = (h_f + x_e h_{fg}) @ 1bar$$

$$x_e = \left(\frac{h_e - h_f}{h_{fg}}\right) @ 1bar = \frac{2610.585 - 417.46}{2258} = 0.97$$

Example 2 SSSF process.

The following readings were obtained from a combined throttling and separating Calorimeter. water from separator 1.5 kg, Steam Condensed after throttling 32 kg, Steam temperature before throttling 170°C, after throttling 110°C. the pressure after throttling 1.01325 bar. Calculate the quality of the Steam before the Calorimeter.

Sol.



$Q = 0$

$W = 0$

mass Conservation.

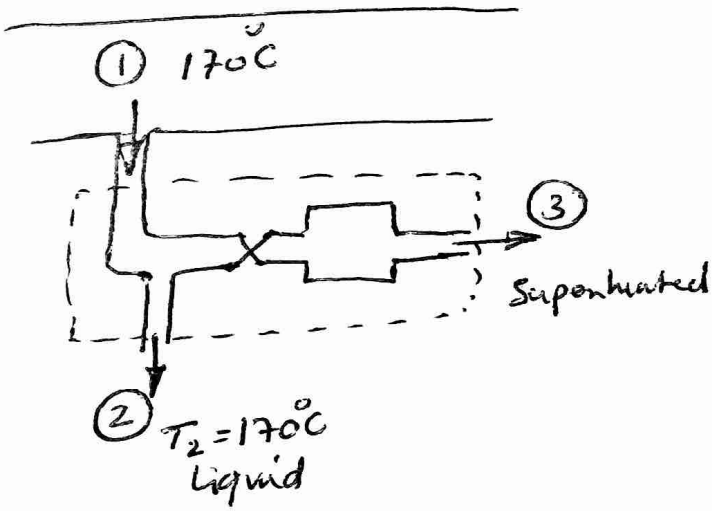
$\dot{m}_1 = \dot{m}_2 + \dot{m}_3 = 33.5 kg.$

First Law

$\sum \dot{m}_i h_i = \sum \dot{m}_e h_e$

$\dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3$

$$h_1 = \frac{\dot{m}_2 h_2 + \dot{m}_3 h_3}{\dot{m}_1}$$



$h_2 = cT = 711 \frac{kJ}{kg}$

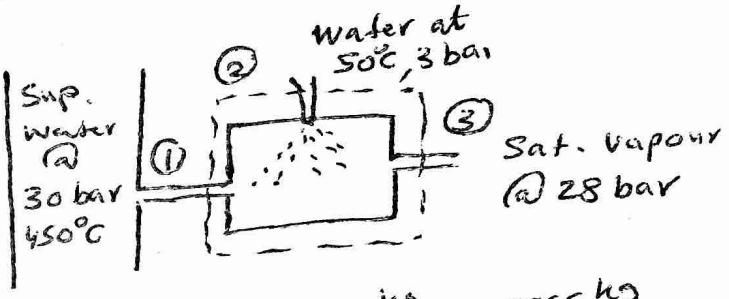
$h_3 @ \begin{matrix} 110°C \\ 1.01325 \end{matrix} = 2696 \frac{kJ}{kg}.$

$h_1 = 2607 \frac{kJ}{kg}$. & $h_g @ 170°C = 2768.7 \frac{kJ}{kg} > h_1$ .. Sat. water

$$x_1 = \left(\frac{h_1 - h_f}{h_{fg}}\right) @ 170°C = \frac{2607 - 719.21}{2049.5} = \underline{\underline{0.92}}$$

.ample 3

In Certain Situations a need For Saturated Steam may arise when only Superheated steam is ~~available~~ available. This can be accomplished in a desuperheater, in which is sprayed into the Superheated Steam in Such a quality that the steam leaving is dry saturated. The Following data apply to Such a desuperheater wich operates as Steady flow process 2000 $\frac{kg}{hr}$ of Superheated Steam at 30 bar and 450°C enter the desperheater together with water at 3 bar and 50°C. The dry saturated vapour leaves at 28 bar. Calculat the rate of flow of water



Sol.

For SSSF process

$\Sigma \dot{m}_i = \Sigma \dot{m}_e$

$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

$\Sigma \dot{m}_i h_i = \Sigma \dot{m}_e h_e$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3 = \dot{m}_1 h_3 + \dot{m}_2 h_3$

$\dot{m}_2 h_2 - \dot{m}_2 h_3 = \dot{m}_1 h_3 - \dot{m}_1 h_1 \Rightarrow \dot{m}_2 (h_2 - h_3) = \dot{m}_1 (h_3 - h_1)$

$$\dot{m}_2 = \frac{\dot{m}_1 (h_3 - h_1)}{h_2 - h_3}$$

$h_1 @ {}^{450°C}_{30\,bar}$ is superheated $= 3344 \frac{kJ}{kg}$.

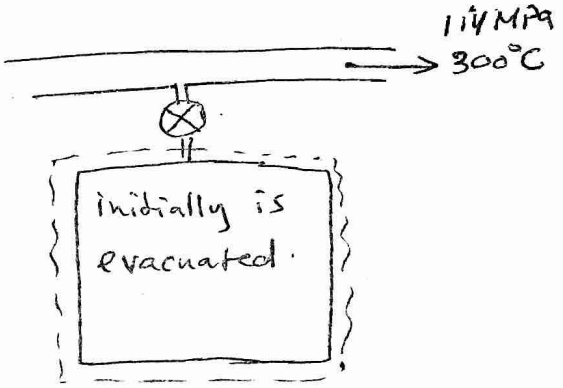
$h_2 @ 50°C$ is comp. liquid $= 209 \frac{kJ}{kg}$.

$h_3 @ 28\,bar$ is Sat. vapour $= h_g @ 28\,bar = 2803.76 \frac{kJ}{kg}$.

$$\therefore \dot{m}_2 = 0.5556 \frac{(2803.76 - 3344)}{209 - 2803.76} = 0.11567 \frac{kg}{sec} = 416.4 \frac{kg}{hr}$$

ample For USUF

Steam at a pressure of 1.4 MPa, 300°C is flowing in a pipe, as Show in the Figure. Connected to this pipe through a valve is an evacuated tank. The valve is opend and the tank fills with Steam until the pressure is 1.4 MPa, and then the valve is closed. The procan takes place adiabatically and kinetic energy and potential energy are negligible. Calculate the final temp. of the Steam in the tank.



$Q = 0 \quad \Delta KE = 0 \quad \Delta PE = 0$

$W = 0$

For Uniform Flow.

$(m_2 - m_1)_{C.V} + m_e - m_i = 0$

$m_2 - m_i = 0 \quad \therefore m_i = m_2$

First Law

$m_2 u_2 = m_i h_i$

$\boxed{u_2 = h_i}$

∴ at the final state [2]

$T_2 = ?$

$u_2 = h_i @ {}^{1.4\,MPa}_{300^\circ C} = 3040.4 \frac{kJ}{kg}$.

$P_2 = 1.4$ MPa.

from Steam Tables of water at Superheated

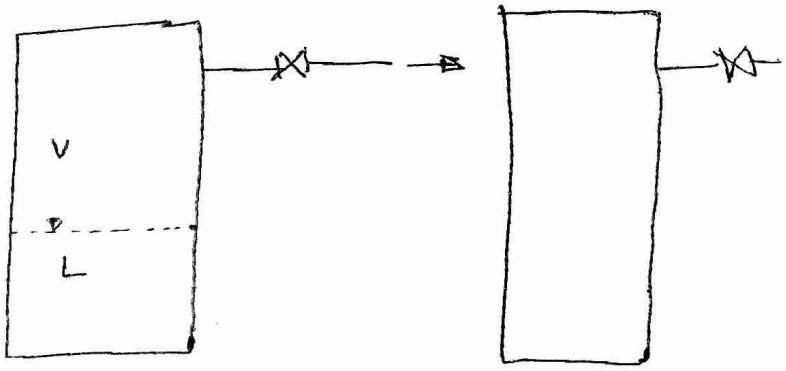
$T_2 @ {}^{u_2 = 3040.4\ kJ/kg}_{P_2 = 1.4\ MPa} = \underline{452^\circ C}$

USUF process.

(5)

tank having a volume of $0.85\ m^3$, initially contains water as two phase liquid – vapour at 260°C and a quality of 0.7. Saturated water vapour at 260°C is slowly withdraw through a pressure-regulating valve at the Top of the tank as energy is transferred by heat to maintain the pressure constant in the tank. This continues until the tank is filled with saturated vapour at 260°C. Calculate the amount of heat transfer, in KJ. Neglect all KE, PE effect

Sol.



$\dot{W} = 0$

$m_2 - m_1 + m_e - m_i = 0$

$m_2 - m_1 = -m_e$

$m_e = m_1 - m_2$

First Law

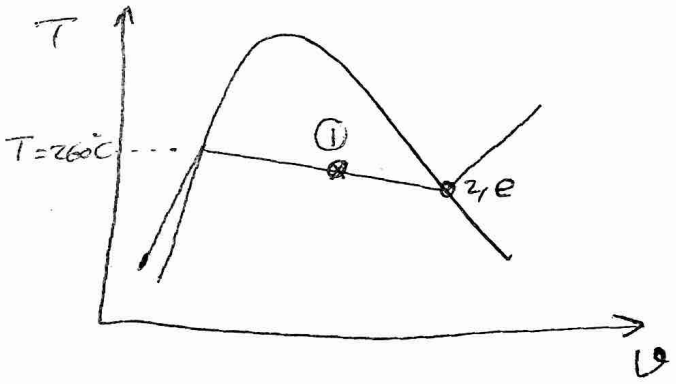
$m_2u_2 - m_1u_1 = -m_e h_e + Q_{c.v}$

$m_2u_2 - m_1u_1 = (m_2 - m_1)h_e + Q_{c.v}$

$(m_2u_2 - m_2h_e) - m_1u_1 + m_1h_e = Q_{c.v}$

$(m_2u_2 - m_2h_e) + (m_1h_e - m_1u_1) = Q_{c.v}$

$m_2(u_2 - h_e) + m_1(h_e - u_1) = Q_{c.v}$



$m_1 = \frac{V_1}{v_1}$ $v_1 = v_f + x_1 v_{fg} = 29.93 \times 10^{-3}\ \frac{m^3}{kg}$

$m_1 = \frac{0.85}{29.93 \times 10^{-3}} = 28.4\ kg$

$v_2 = v_g @ 260°C = 42.21 \times 10^{-3}\ \frac{m^3}{kg} \Rightarrow m_2 = \frac{V}{v_2} = \frac{0.85}{42.21 \times 10^{-3}} = 20.14\ kg$

$u_1 = (u_f + x_1 u_{fg}) @ 260°C = 2157.8\ \frac{kJ}{kg}$, $u_2 = u_g @ 240°C = 2599\ \frac{kJ}{kg}$

$h_e = h_g @ 260°C = 2796.6\ \frac{kJ}{kg}$ $\therefore Q_{c.v} = 1416.2\ KJ$